CLAIMS

1. A method for producing an optical element, comprising:

a step of forming a proton exchange layer in an $LiNb_xTa_{1-x}O_3$ ($0 \le X \le 1$) substrate; and

an annealing step of performing a heat treatment for the substrate at a temperature of 120°C or lower for 1 hour or more.

2. A method for producing an optical element according to claim 1, wherein the annealing step is performed at a temperature equal to or higher than 50°C but lower than or equal to 90°C.

3. A method for producing an optical element according to claim 1, wherein the annealing step comprises a step of gradually lowering the temperature.

4. A method for producing an optical element according to claim 1, wherein the step of forming the proton exchange layer comprises:

a step of performing a proton exchange process for the substrate; and a step of performing a heat treatment for the substrate at a temperature of 150°C or higher.

5. A method for producing an optical element according to claim 4, wherein the annealing step is performed at a temperature equal to or higher than 50°C but lower than or equal to 90°C.

6. A method for producing an optical element according to claim 4, wherein the annealing step comprises a step of

gradually lowering the temperature.

7. A method for producing an optical element according to claim 1, wherein the step of forming the proton exchange layer comprises: a step of forming a plurality of periodically-arranged domain inverted layers in the substrate; and a step of forming an optical waveguide on a surface of the substrate.

8. A method for producing an optical element, comprising:

a step of performing a proton exchange process for an $LiNb_xTa_{1-x}O_3$ $(0 \leq X \leq 1)$ substrate; and

an annealing step of performing a plurality of heat treatments including at least first and second heat treatments for the substrate, wherein

a temperature of the second annealing is lower than a temperature of the first annealing by 200°C or more.

9. A method for producing an optical element according to claim 8, wherein the second annealing is performed at a temperature equal to or higher than 50°C but lower than or equal to 90°C.

10. An optical element, comprising an $LiNb_xTa_{1-x}O_3$ $(0 \leq X \leq 1)$ substrate and a proton exchange layer formed in the substrate, wherein

the optical element is formed of a stable proton exchange layer such that a refractive index of the proton exchange layer does not vary with time during operation.

11. An optical element according to claim 10, wherein at least a portion of the proton exchange layer forms an

optical waveguide.

12. A light source comprising: a semiconductor laser; and an optical wavelength conversion element for receiving laser light emitted from the semiconductor laser so as to convert the laser light to a harmonic wave, wherein:

the optical wavelength conversion element includes: an optical waveguide for guiding the laser light; and domain inverted structures periodically arranged along the optical waveguide, the optical waveguide and the domain inverted structures being formed of a stable proton exchange layer whose refractive index does not vary with time during operation.

13. A laser light source comprising:

a semiconductor laser for emitting a fundamental wave;

a single mode fiber for conveying the fundamental wave; and

an optical wavelength conversion element for receiving the fundamental wave emitted from the fiber so as to generate a harmonic wave, the optical wavelength conversion element having periodic domain inverted structures.

14. A laser light source according to claim 13, wherein the optical wavelength conversion element has a modulation function.

15. A laser light source according to claim 13, wherein the optical wavelength conversion element is formed in an $LiNb_xTa_{1-x}O_3$ ($0 \le X \le 1$) substrate.

16. A laser light source, comprising:

a semiconductor laser for emitting a pumped light;

a fiber for conveying the pumped light;

a solid state laser crystal for receiving the pumped light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for receiving the fundamental wave so as to generate a harmonic wave, the optical wavelength conversion element having periodic domain inverted structures.

17. A laser light source according to claim 16, wherein the optical wavelength conversion element has a modulation function.

18. A laser light source according to claim 16, wherein the optical wavelength conversion element is formed in an $LiNb_xTa_{1-x}O_3$ ($0 \le X \le 1$) substrate.

19. A laser light source according to claim 16, wherein the solid state laser crystal and the optical wavelength conversion element are integrated together.

20. A laser light source, comprising:

a semiconductor laser for emitting a pumped light;

a solid state laser crystal for receiving the pumped light so as to generate a fundamental wave;

a single mode fiber for conveying the fundamental wave; and

an optical wavelength conversion element for receiving the fundamental wave from the fiber so as to

generate a harmonic wave, the optical wavelength conversion element having periodic domain inverted structures.

21. A laser light source according to claim 20, wherein the optical wavelength conversion element has a modulation function.

22. A laser light source, comprising:

a distributed feedback type semiconductor laser for emitting laser light;

a semiconductor laser amplifier for amplifying the laser light; and

an optical wavelength conversion element for receiving the amplified laser light so as to generate a harmonic wave, the optical wavelength conversion element having periodic domain inverted structures.

23. A laser light source according to claim 22, wherein the optical wavelength conversion element has a modulation function.

24. A laser light source according to claim 22, wherein the optical wavelength conversion element is formed in an $LiNb_xTa_{1-x}O_3$ ($0 \leq X \leq 1$) substrate.

25. A laser light source according to claim 22, wherein the semiconductor laser is wavelength-locked.

26. A laser light source, comprising:

a semiconductor laser for emitting laser light; and

an optical wavelength conversion element in which

periodic domain inverted structures and an optical waveguide are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

27. A laser light source according to claim 26, wherein the optical wavelength conversion element has a modulation function.

28. A laser light source according to claim 26, wherein the optical wavelength conversion element is formed in an $LiNb_xTa_{1-x}O_3$ ($0 \le X \le 1$) substrate.

29. A laser light source according to claim 26, wherein the optical waveguide is of a graded type.

30. A laser device, comprising:

a laser light source having a semiconductor laser for radiating laser light and an optical wavelength conversion element for generating a harmonic wave based on the laser light;

a modulator for modulating an output intensity of the harmonic wave; and

a deflector for changing a direction of the harmonic wave emitted from the laser light source, wherein

periodic domain inverted structures are formed in the optical wavelength conversion element.

31. A laser device according to claim 30, wherein the laser light source comprises:

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength

conversion element.

32. A laser light source according to claim 30, wherein the laser light source comprises:

a fiber for conveying laser light from the semiconductor laser; and

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave.

33. A laser light source according to claim 30, wherein:

the semiconductor laser device is a distributed feedback type semiconductor laser; and

the laser light source further comprises a semiconductor laser amplifier for amplifying the laser light from a distributed feedback type semiconductor laser.

34. A laser light source according to claim 30, wherein:

an optical waveguide is formed in the optical wavelength conversion element; and

a width and a thickness of the optical waveguide are each 40 μm or greater.

35. A laser device, comprising: a laser light source for radiating modulated ultraviolet laser light; and a deflector for changing a direction of the ultraviolet laser light, wherein:

the deflector irradiates a screen with the ultraviolet laser light so as to generate red, green or blue light from a fluorescent substance being applied on the screen.

36. A laser device according to claim 35, wherein the laser light source comprises:

a semiconductor laser;

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

37. A laser light source according to claim 35, wherein the laser light source comprises:

a semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for generating a harmonic wave from the fundamental wave.

38. A laser light source according to claim 35, wherein the laser light source further comprises:

a semiconductor laser; and a semiconductor laser amplifier for amplifying laser light from a distributed feedback type semiconductor laser.

39. A laser light source according to claim 35, wherein the laser light source comprises:

a semiconductor laser for emitting laser light; and

an optical wavelength conversion element in which an optical waveguide for guiding the laser light and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

40. A laser device, comprising:

three laser light sources respectively for generating red, green and blue laser light beams;

a modulator for changing an intensity of each of the laser light beams; and

a deflector for changing a direction of each of the laser light beams, wherein

the laser light source is formed of a semiconductor laser.

41. A laser device according to claim 40, wherein the laser light source comprises:

a semiconductor laser;

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

42. A laser light source according to claim 40, wherein the laser light source comprises:

a semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for generating a harmonic wave from the fundamental wave.

43. A laser light source according to claim 40, wherein the laser light source further comprises:

a semiconductor laser; and a semiconductor laser amplifier for amplifying laser light from a distributed feedback type semiconductor laser.

44. A laser light source according to claim 40, wherein the laser light source comprises:

a semiconductor laser for emitting laser light; and

an optical wavelength conversion element in which an optical waveguide for guiding the laser light and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

45. A laser device, comprising:

at least one laser light source including a semiconductor laser;

a sub-semiconductor laser;

a modulator for changing an intensity of light from the laser light source;

a screen; and

a deflector for changing a direction of light from the laser light source so as to scan the screen with the light, wherein:

light emitted from the sub-semiconductor laser scans a peripheral portion of the screen; and radiation of laser light from the laser light source is terminated when an optical path of the light emitted from the sub-semiconductor laser is blocked.

46. A laser device according to claim 45, wherein the laser light source comprises:

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

47. A laser light source according to claim 45, wherein the laser light source comprises:

the semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for generating a harmonic wave from the fundamental wave.

48. A laser light source according to claim 45, wherein:

the semiconductor laser is a distributed feedback type semiconductor laser; and the laser light source further comprises a semiconductor laser amplifier for amplifying laser light from the distributed feedback type semiconductor laser.

49. A laser light source according to claim 45, wherein the laser light source comprises:

an optical wavelength conversion element in which an optical waveguide for guiding laser light from the semiconductor laser and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide

are each 40 μm or greater.

50. A laser device, comprising:

at least one laser light source including a semiconductor laser;

a deflector for changing a direction of laser light radiated from the laser light source so as to scan the screen with the laser light, wherein:

the device further comprises two or more detectors for generating a signal when receiving a portion of the laser; and

generation of laser light from the laser light source is terminated when the detector does not generate a signal for a certain period of time while the deflector scans the screen with the laser light.

51. A laser device according to claim 50, wherein the laser light source comprises:

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

52. A laser light source according to claim 50, wherein the laser light source comprises:

the semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for

generating a harmonic wave from the fundamental wave.

53. A laser light source according to claim 50, wherein:

the semiconductor laser is a distributed feedback type semiconductor laser; and the laser light source further comprises a semiconductor laser amplifier for amplifying laser light from the distributed feedback type semiconductor laser.

54. A laser light source according to claim 50, wherein the laser light source comprises:

an optical wavelength conversion element in which an optical waveguide for guiding laser light from the semiconductor laser and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

55. A laser device, comprising:

at least one laser light source including a semiconductor laser;

a modulator for changing an intensity of each laser light; and

a deflector for changing a direction of each laser light, wherein

laser light emitted from the laser light source is split into two or more optical paths so as to irradiate a screen from two directions.

56. A laser device according to claim 55, wherein the laser light source comprises:

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

57. A laser light source according to claim 55, wherein the laser light source comprises:

the semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for generating a harmonic wave from the fundamental wave.

58. A laser light source according to claim 55, wherein:

the semiconductor laser is a distributed feedback type semiconductor laser; and the laser light source further comprises a semiconductor laser amplifier for amplifying laser light from the distributed feedback type semiconductor laser.

59. A laser light source according to claim 55, wherein the laser light source comprises:

an optical wavelength conversion element in which an optical waveguide for guiding laser light from the semiconductor laser and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

60. A laser device according to claim 55, wherein: two optical paths are formed by two laser light sources; and

the laser light sources respectively experience different modulations.

61. A laser device according to claim 55, wherein the two optical paths are switched with each other based on time.

62. A laser device, comprising:

at least one laser light source including a semiconductor laser;

a first optical system for setting laser light emitted from the laser light source into a parallel beam;

a liquid crystal cell for spatially modulating the parallel beam; and

a second optical system for irradiating a screen with light emitted from the liquid crystal cell.

63. A laser device according to claim 62, wherein the laser light source comprises:

an optical wavelength conversion element for generating a harmonic wave; and

a single mode fiber for conveying laser light from the semiconductor laser to the optical wavelength conversion element.

64. A laser light source according to claim 62, wherein the laser light source comprises:

the semiconductor laser;

a fiber for conveying laser light from the semiconductor laser;

a solid state laser crystal for receiving laser light emitted from the fiber so as to generate a fundamental wave; and

an optical wavelength conversion element for

generating a harmonic wave from the fundamental wave.

65. A laser light source according to claim 62, wherein:

the semiconductor laser is a distributed feedback type semiconductor laser; and the laser light source further comprises a semiconductor laser amplifier for amplifying laser light from the distributed feedback type semiconductor laser.

66. A laser light source according to claim 62, wherein the laser light source comprises:

an optical wavelength conversion element in which an optical waveguide for guiding laser light from the semiconductor laser and periodic domain inverted structures are formed, wherein

a width and a thickness of the optical waveguide are each 40 μm or greater.

67. A laser device according to claim 45, wherein the sub-semiconductor laser is an infrared laser.

68. A laser device according to claim 45, wherein laser light radiation is terminated by shifting a phase-matched wavelength of the optical wavelength conversion element.

69. An optical disk apparatus, comprising: a laser light source for generating laser light; an optical wavelength conversion element for converting a fundamental wave to a harmonic wave; an optical pickup incorporating therein the optical wavelength conversion element; and an actuator for moving the optical pickup, wherein

the laser light radiated from the laser light source is incident upon the optical pickup via an optical

fiber.

70. An optical disk apparatus according to claim 69, wherein the laser light source includes a semiconductor laser disposed outside the optical pickup.

71. An optical disk apparatus according to claim 70, wherein the laser light source further comprises a solid state laser crystal for generating a fundamental wave using laser light emitted from the semiconductor laser as pumped light.

72. An optical disk apparatus according to claim 71, wherein: the solid state laser crystal is disposed outside the optical pickup; and the fundamental wave generated by the solid state laser medium is incident upon the optical wavelength conversion element via the optical fiber.

73. An optical disk apparatus according to claim 71, wherein: the solid state laser crystal is disposed inside the optical pickup; and the laser light emitted from the semiconductor laser is incident upon the solid state laser via the optical fiber.

74. A laser light source according to claim 30, wherein a harmonic wave is superimposed over the semiconductor laser during operation.

75. A laser light source according to claim 40, wherein a harmonic wave is superimposed over the semiconductor laser during operation.